

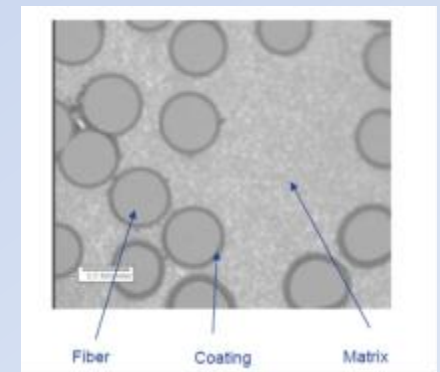
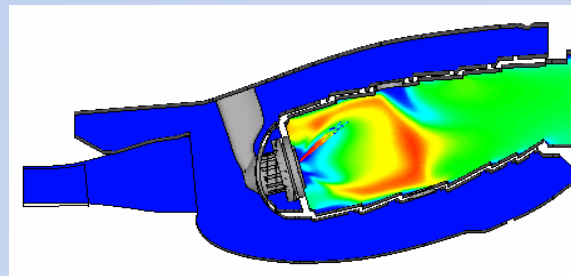
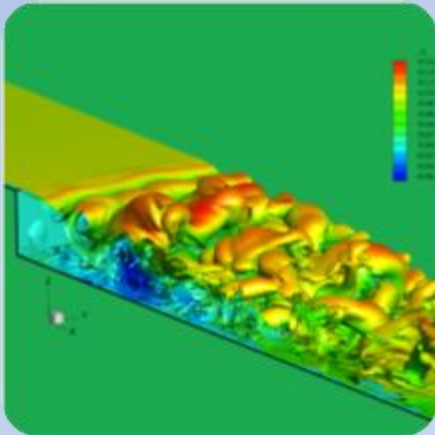
Aeronautical Sciences Project Overview

Acoustics Technical Working Group
Apr. 23, 2013

Manager: Jim Heidmann (GRC)

Deputy Manager: Stan Smeltzer (LaRC)

Project Scientist: Mike Rogers (ARC)





NASA Fundamental Aeronautics Program Structure

Aeronautical Sciences Project Objectives

Aeronautical Sciences Project Team

Technical Disciplines & Key Research Activities

Summary

NASA Aeronautics Programs



Fundamental Aeronautics Program

Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment



Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.

Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.



Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

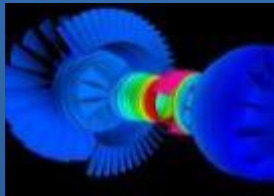
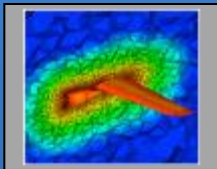


FA Program Organization Structure



Fundamental Aeronautics Program Office

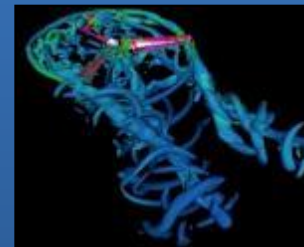
Aeronautical Sciences Project



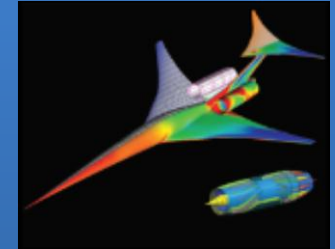
Fixed Wing Project



Rotary Wing Project



High Speed Project



Aeronautical Sciences (AS)

Enable fast, efficient design & analysis of advanced aviation systems by developing physics-based tools and methods for cross-cutting technologies.

Fixed Wing (FW)

Explore & develop technologies and concepts for improved energy efficiency & environmental compatibility of fixed wing, subsonic transports

Rotary Wing (RW)

Develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles

High Speed (HS)

Enable tools & technologies and validation capabilities necessary to overcome environmental & performance barriers to practical civil supersonic airliners. 4

Aeronautical Sciences Connectivities



Fundamental Aeronautics Program

Rotary Wing
Project



Fixed Wing
Project



High Speed
Project



NASA SME
Input

Aeronautical Sciences Project

Multi-Disciplinary Analysis & Optimization

Fluids
& Combustion

Structures
& Materials

Instrumentation
& Controls

External
Stakeholders

Aeronautics
Seedling Fund

Aeronautical Sciences Project



*Why **NASA** for Foundational Aeronautics Research?*

NASA's Aeronautics Research Mission Directorate (ARMD) works to solve the challenges that still exist in our nation's air transportation system: air traffic congestion, safety and environmental impacts.

Solutions to these problems require **innovative technical concepts**, and **dedicated research and development**. NASA's ARMD pursues the development of new flight operation concepts, and **new tools and technologies** that can transition smoothly to industry to become products.

National **Aeronautics** and Space Administration

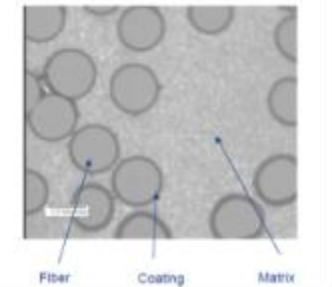
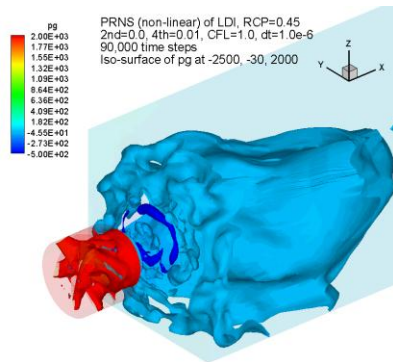


Aeronautical Sciences Project



Why “Aeronautical Sciences”?

NASA Aeronautics requires a home to champion foundational, cross-cutting aeronautics scientific research...



NASA's Aeronautical Sciences Project

New project as of October 2012

Aeronautical Sciences Project

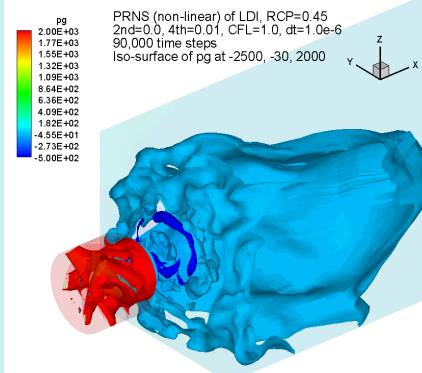
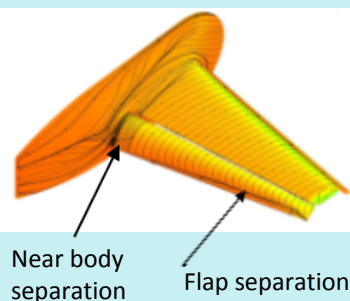
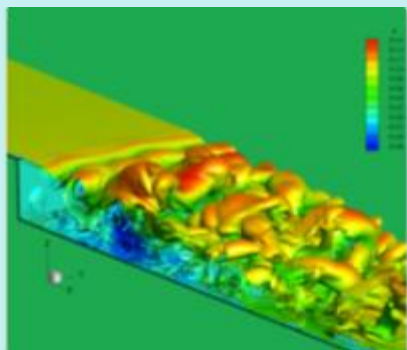
Enable fast, efficient design & analysis of advanced aviation systems from first principles by developing physics-based tools/methods & cross-cutting technologies, provide new MDAO & systems analysis tools, & support exploratory research with the potential to result in breakthroughs

Vision

- Physics-based predictive methods for improved analysis and design
- Leverage improved understanding and discipline integration toward improved future air vehicles

Scope

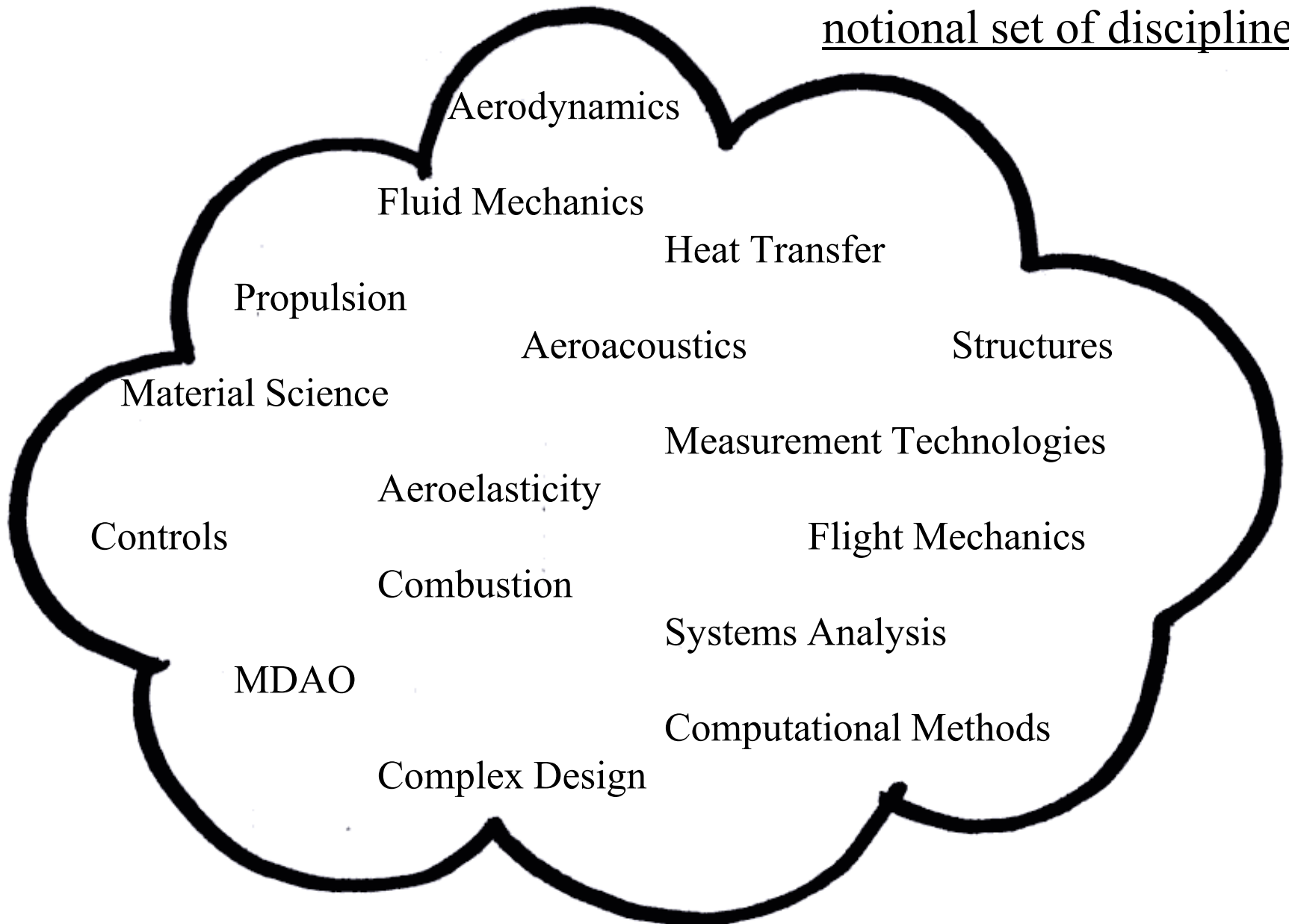
- Foundational research and technology for civil air vehicles
- Discipline-based research and system-level integration method development



What Are the Foundational Aeronautics Sciences?

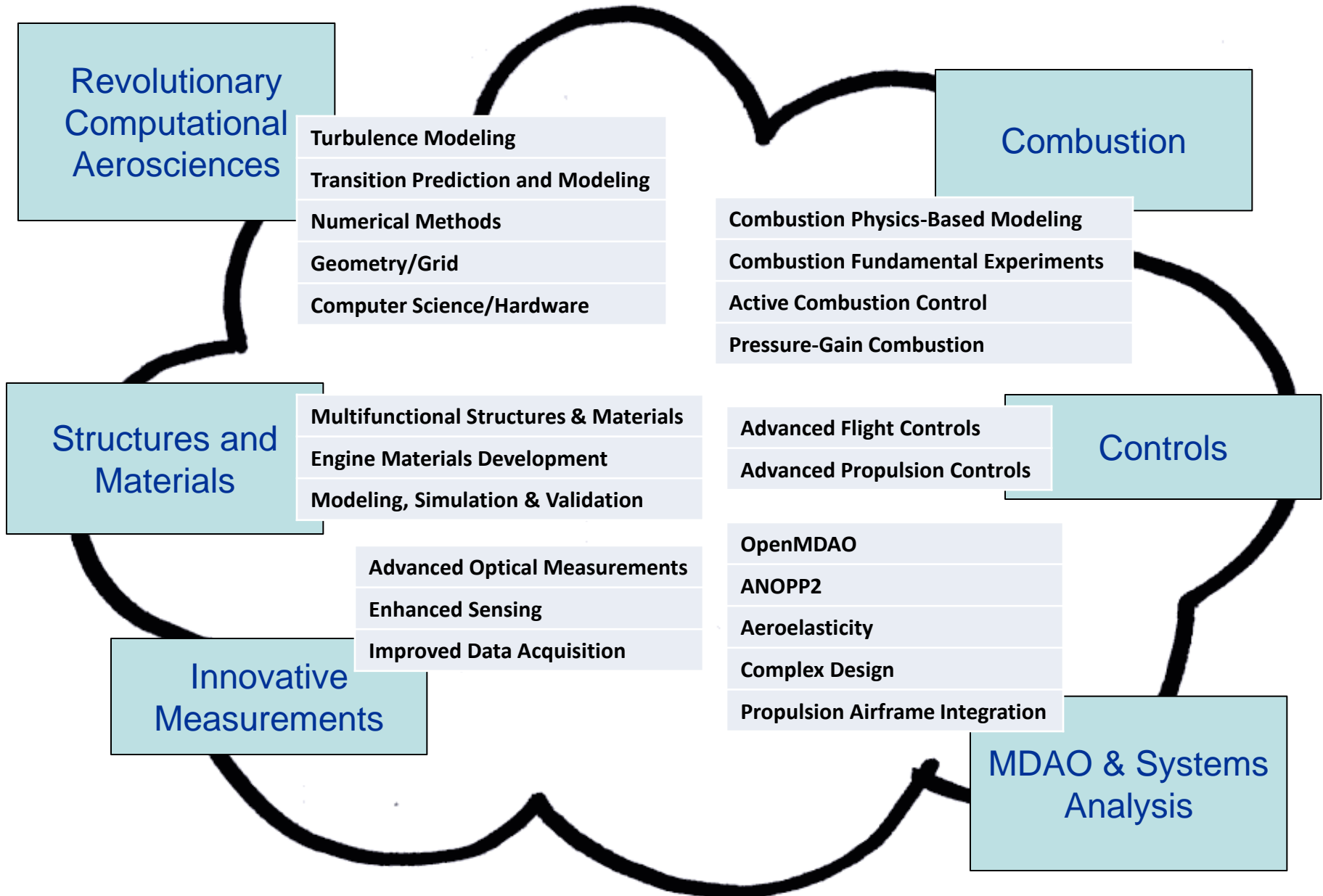


notional set of disciplines





Aeronautical Sciences Project Disciplines



Aeronautical Sciences Project Organization



PROJECT
LEVEL

- Organized by technical disciplines
- Technical leads for disciplines providing overall technical direction and oversight

Project Manager: Jim Heidmann (GRC)

Deputy Project Manager: Stan Smeltzer (LaRC)

Project Scientist: Mike Rogers (ARC)

Business Integration Manager: Jacob Jevic (GRC)

Dryden POC: Mark Davis (DFRC)

Scheduler: Joyce Moran (GRC)

ARC

Program Analyst:
Sandra Ramirez

DFRC

Program Analyst:
Becky Miani

GRC

Program Analyst:
Tom Halstead

LaRC

Program Analyst:
Julie Fowler

TECHNICAL DISCIPLINES

Revolutionary Computational
Aerosciences:
Mujeeb Malik (LaRC)

Structures and Materials:
Dale Hopkins (GRC)

MDAO & Systems Analysis:
Jeff Robinson (LaRC)

Combustion:
Dan Bulzan (GRC)

Controls:
Sanjay Garg (GRC)

Innovative Measurements:
Tom Jones (LaRC)

RCA

MDAO

Measurements

SaM

MDAO

Controls

Measurements

RCA

SaM

MDAO

Combustion

Controls

Measurements

RCA

SaM

MDAO

Controls

Measurements

Revolutionary Computational Aerosciences

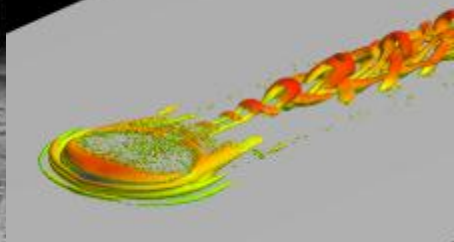
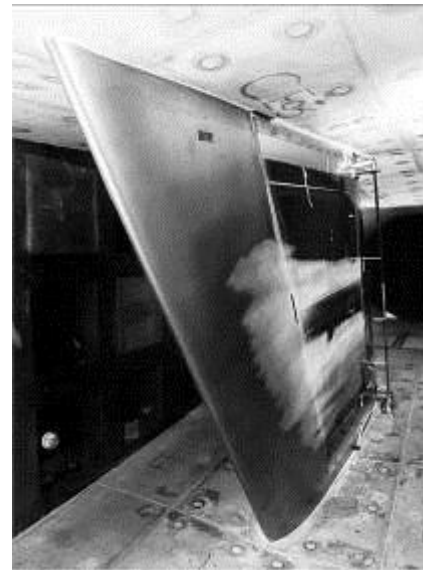
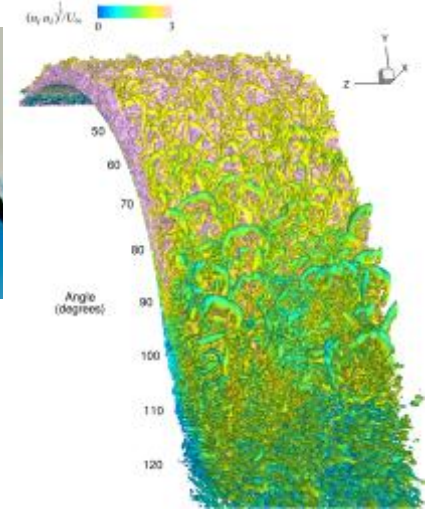


GOAL:

Identify and down select critical turbulence, transition, and numerical method technologies for improved prediction of turbulent separated flows, evolution of free shear flows and shock-boundary layer interactions on state-of-the-art high performance computing hardware.

APPROACH:

- Turbulence Modeling (and associated validation experiments)
- Transition Prediction and Modeling (and associated validation experiments)
- Numerical Methods
- Validation/Prediction Workshops
- RCA Institute



Technical Challenge: Physics-Based Turbulence Models



Objective

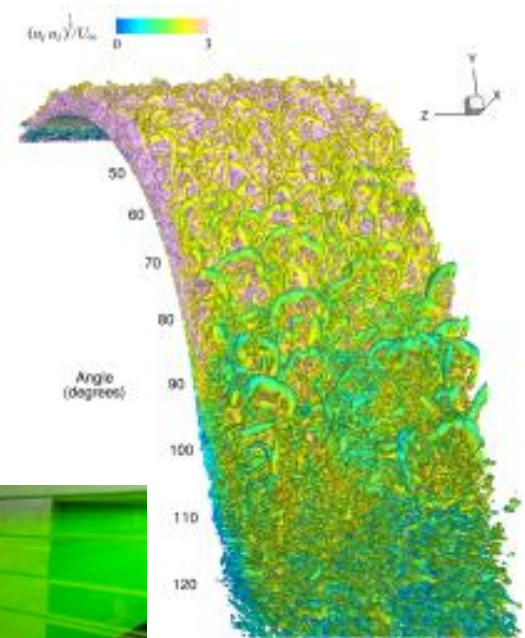
Identify and downselect critical turbulence, transition, and numerical method technologies for improved (by 40%) prediction of turbulent separated flows, evolution of free shear flows and shock-boundary layer interactions on state-of-the-art high performance computing hardware.

Technical Areas and Approaches

- Development of more accurate physics-based methods (e.g. large eddy simulation (LES))
- Validation experiments
- Advanced numerical methods

Benefit/Pay-off

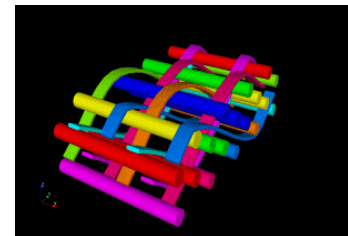
- Capability will be used by the aeronautics community to improve designs and reduce design cycle times
- Facilitates accelerated introduction of advanced air vehicles and propulsion systems into the airspace system.



- Demonstrate **multi-functional structures & materials** that reduce weight by simultaneously meeting multiple airframe or engine requirements
- Develop **high temperature engine materials** and associated design tools and life prediction methodology to reduce or eliminate the need for turbine cooling
- Develop a **computational materials design and optimization** capability for airframe & engine materials



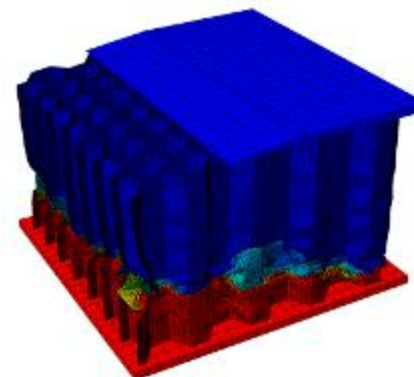
Exhaust-Washed Structures



Advanced 3D fiber architecture



EBC-coated CMC vane



Analysis tools simulate failure process

Technical Challenge: High Temperature Materials

Objective

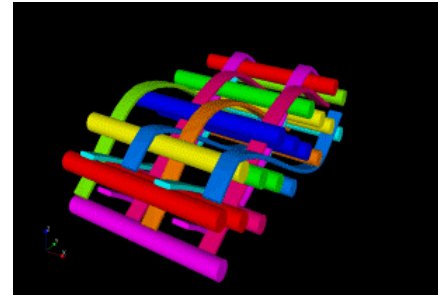
Develop high-temperature materials for turbine engines that enable a 6% reduction in fuel burn for commercial aircraft, compared to current SOA materials.

Technical Areas and Approaches

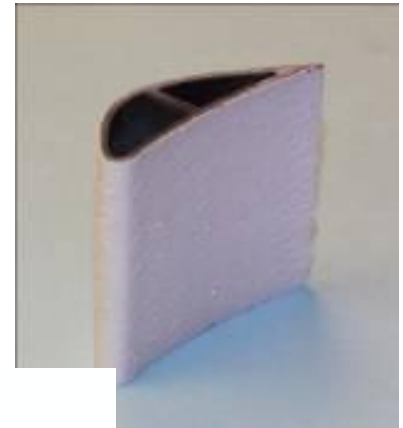
- Ceramic matrix composite (CMC) materials and the required high-temperature environmental barrier coatings (EBCs) are investigated and developed.
- Modeling and simulation tool development

Benefit/Pay-off

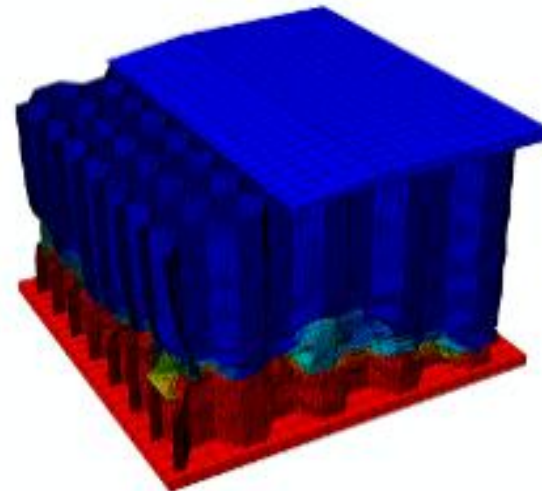
- Enables increased engine operating temperature and/or reducing or eliminating the need for engine component cooling
- Improves efficiency and helps reduce emissions



Advanced 3D Fiber Architecture



EBC-Coated CMC Vane



Analysis Tools Simulate Failure Process

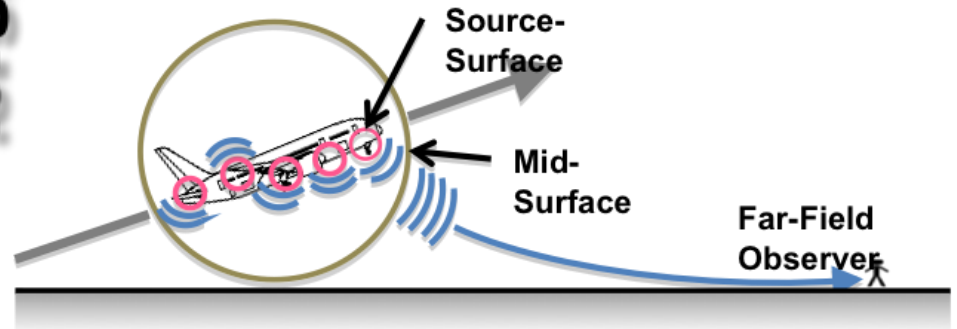
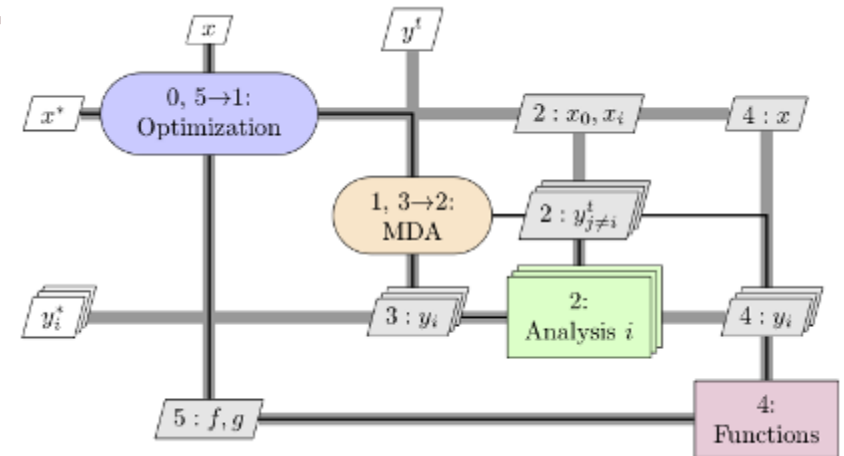
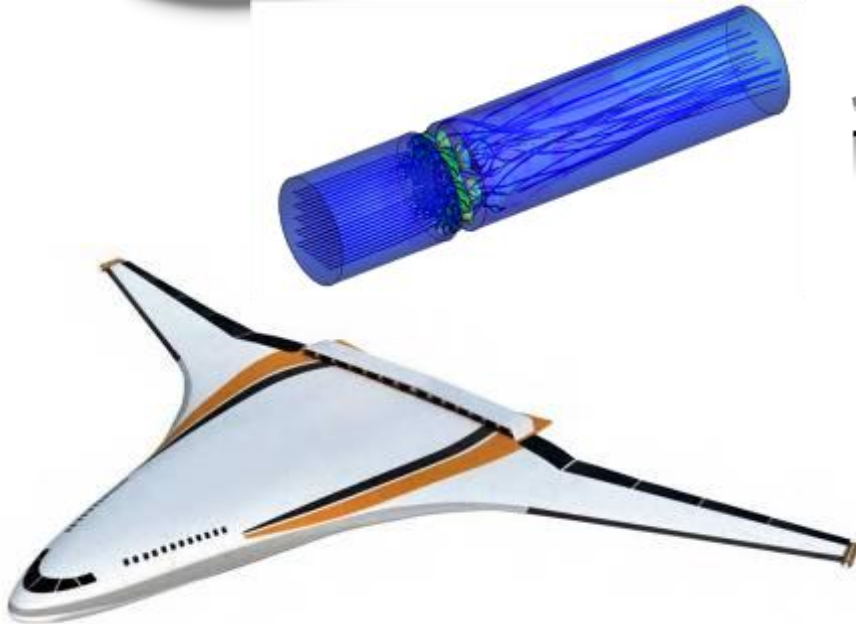
MDAO & Systems Analysis



Goals:

- Develop new methods for multi-disciplinary and multifidelity analysis of unconventional aerospace concepts
- Integration of multidisciplinary analyses with a common geometry model
- Reduce the upfront cost of applying MDAO to aerospace design problems

OpenMDAO.org



Approach:

- Tool development at multiple levels of fidelity
- Use of an open source framework as a common engineering platform
- Use of geometry tools that can serve multiple analysis tools and provide analytic derivatives for efficient optimization
- Use of challenge problems to demonstrate capabilities

Next Generation Multi-Fidelity Aircraft Noise Prediction Capability: ANOPP2



FAP – Aeronautical Sciences Project

PROBLEM

NASA provides the U.S. Government with tools for independent assessment of aircraft system noise and annoyance. NASA Aircraft NOise Prediction Program (ANOPP) started over 30 years ago and is primarily “fixed” fidelity, point source empirical methods, greatly limiting its application to existing and future aircraft designs.

OBJECTIVE

Provide software framework that allows noise prediction for arbitrary aircraft designs (conventional to unconventional), of full-scale and model-scale size by accommodating multi-fidelity analyses from semi-empirical predictions for design to high-fidelity, physics-based predictions to study noise generation, propagation, human annoyance (auralization), and reduction and interface with system level frameworks.

SIGNIFICANCE

ANOPP2 will provide NASA and other government agencies (FAA, DoD, etc) with tools to independently assess aircraft noise and its effects. Potential payoff is significant advantage in the marketplace for the U.S. aircraft industry through production of quieter, more acceptable aircraft while maintaining aerodynamic efficiency.

APPROACH

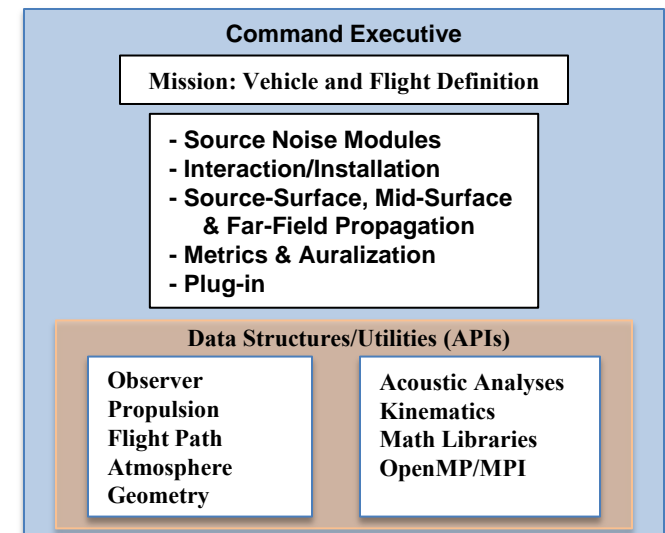
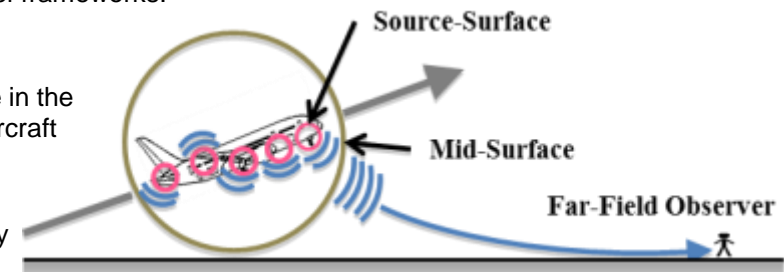
- Establish a framework where combination of acoustic prediction methods of varied fidelity communicate in a unified system.
- Create a system of Application Programming Interfaces (APIs) enabling building block approach to provide user ‘unlimited’ control of the noise prediction process.
- Suite of APIs provide tools to implement and create predictions modules for ANOPP2.
- Self testing, documenting, and verification enable automated ANOPP2 builds/distribution
- Varied fidelity prediction through use of nested Ffowcs Williams & Hawkins (FW-H) surfaces.
- Data Structures & Command Executive enable nested FW-H approach Fortran 2008 object-oriented programming
- Concurrent aircraft noise assessment of capabilities throughout development, customer as part of development team

PROGRESS TO DATE

- Observer, Propulsion, Flight Path, Atmosphere, Geometry, and Kinematic data structures designed & implemented, testing and documentation underway.
- Observer functionality to accommodate noise suppression enables testing of noise scattering methods. Initial demonstration of prediction-based tools to auralize flyover noise from arbitrary aircraft configurations, flying arbitrary operations, in arbitrary atmospheres.
- ANOPP2 libraries working on Windows, Linux and Mac
- Design of plugin capability for external prediction methods and implementation complete. Testing underway.
- Draft documentation, automated build/verification processes completed and in use

POC: Casey Burley (LaRC), Leonard Lopes (LaRC)

MDAO

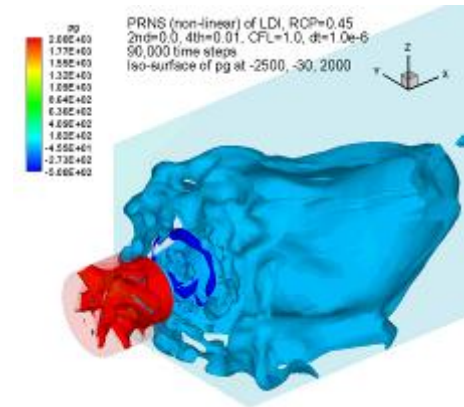


GOAL:

Improve combustion CFD modeling tools and develop new laser diagnostics techniques to improve understanding of combustion processes and concepts that have the potential to meet NASA emissions goals for future aircraft engines.



Raman Calibration Facility



Non Reacting Single Element LDI
Flowfield Structure using TFNS

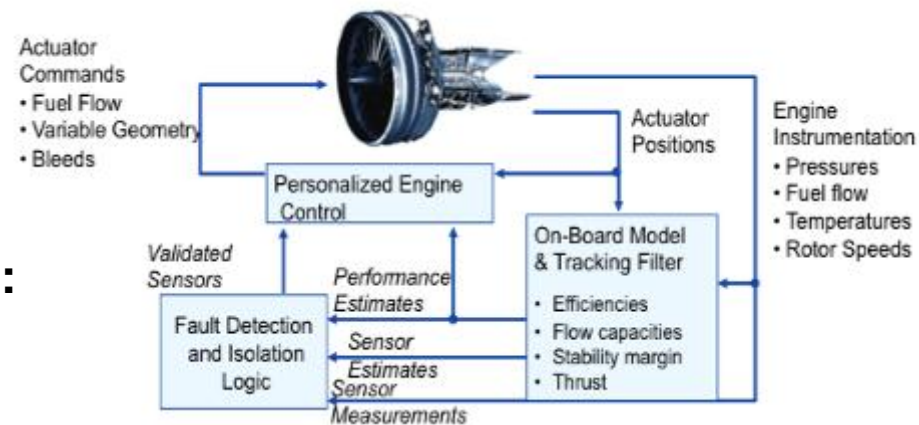
APPROACH:

- Combustion Physics-Based Modeling
- Combustion Fundamental Experiments
- Active Combustion Control
- Pressure Gain Combustion

- **High Level Objective:** Develop advanced control technologies to enable new capabilities for efficient and autonomous operation of aircraft and propulsion systems
- **Advanced Flight Controls:**
 - Relative Navigation and Sensor Fusion for Formation Flight - DFRC
 - Advanced Control Methods for Autonomy - LaRC
 - Learn to Fly - LaRC
- **Advanced Propulsion Controls (GRC):**
 - Distributed Engine Control
 - Model Based Engine Control
 - Plasma Actuators for Flow Control



Formation Flight



Model-Based Engine Control

Innovative Measurements



PROBLEM

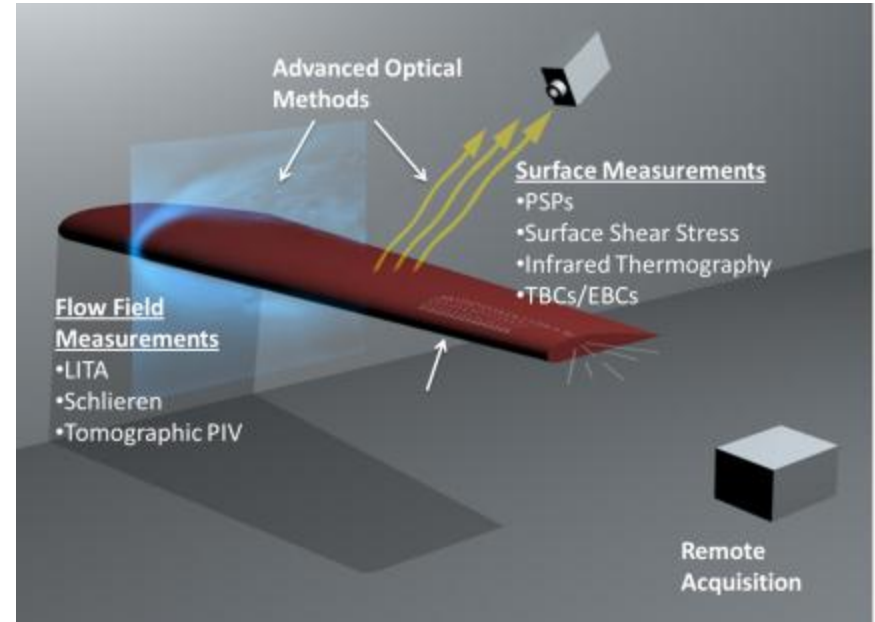
Measurement science technologies have limited fidelity robustness, range of applicability.

OBJECTIVE

Develop and implement advanced capabilities and diagnostic methods to meet measurement challenges not being achieved by techniques currently utilized in NASA ground testing, flight experiments and airframe/engine diagnostics. Developments should be cross-cutting for the vehicle spectrum within FAP.

APPROACH

- Leveraging center expertise from all four research centers to produce integrated instrumentation approaches.
- Emphasize linkages/partnerships with other AS sub-projects and FA projects to fully establish the critical need for this work.
- Partner with ATP to coordinate investments.



SIGNIFICANCE

This will enable new methods for obtaining critical experimental data for validation of computational methods and for diagnostics of airframe and engine components.

MEMS Shear Stress Sensors



FAP – Aeronautical Sciences Project

PROBLEM

The measurement of shear stress has been the focus of significant effort for many years. Reliable quantitative values, especially two component have been difficult to impossible to obtain except in certain limited situations.

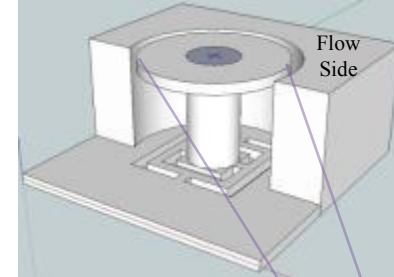
OBJECTIVE

Improved packaging and testing of MEMS two-component direct shear stress sensors to facilitate quantitative shear stress data in ground test facilities and/or flight test vehicles.

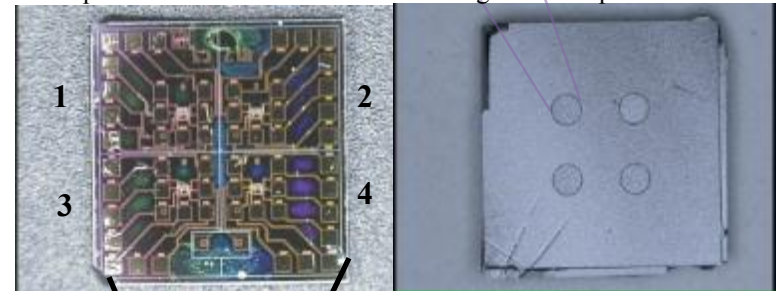
SIGNIFICANCE

Direct shear stress measurements are considered one of the key measurements when assessing drag and drag reduction technologies. **A new application of significant interest is the measurement of shear stress over acoustic liners in the presence of sound. This never before measured information of drag induced by various liner configurations has become of major interest due to potential for increased noise treatments of aircraft.** Relative drag could become a performance criteria in liner design in addition to weight, acoustic performance, and other criteria.

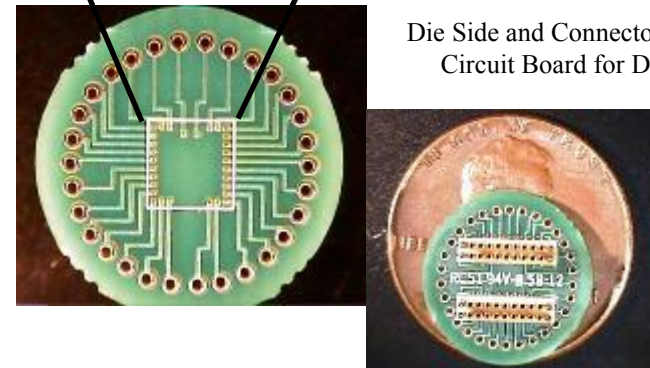
Two Component Shear Stress Sensor
Single Device Concept (partial cutaway for clarity)



Device Side and Flow Side View of Silicon Die with Four Two-Component Shear Stress Sensors and Integrated Temperature Sensor



Die Side and Connector Side View of Circuit Board for Die Mounting



Die/Board Assemblies to be integrated with Langley designed and built housing for test and operation

Simultaneous Flow Field Measurements



FAP – Aeronautical Sciences Project

PROBLEM

Spectral interference limits the ability to perform **simultaneous measurement of several flow field measurements**

OBJECTIVE

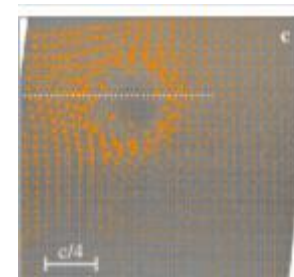
Demonstrate simultaneous acquisition of each test technique without instrument cross-talk through spectral separation of light sources and signals.

APPROACH

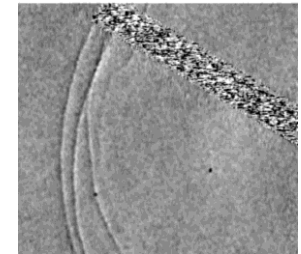
Demonstrate the technique as part of a US Army sponsored rotor test. The test will utilize existing hardware resources. The test technique will be evaluated for adaptability to any fluid-structure interaction test.

SIGNIFICANCE

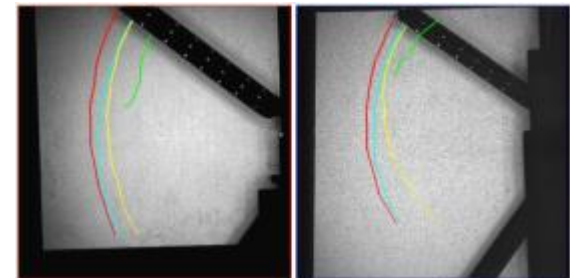
The simultaneous data promote better correlation between on-body and off-body phenomena, and greater efficiency in large scale testing. The development will lead to better the methodologies, database management, and data visualization.



PIV data of tip vortex



Schlieren (RBOS) data of same vortex



Photogrammetric image pair for blade location and tip vortex mapping



Mikado RC Helicopter GMBH; Model Edge 813 mm.
NACA 0020 with swept and rounded tip.

Enhanced Aeroacoustics Measurements: In-Flow Sensors



FAP – Aeronautical Sciences Project

PROBLEM

Level-sensing phased microphone arrays need to be adapted to in-flow operation to improve sensor location options for aeroacoustic research while preserving the benefits of improved signal-to-noise ratio and facility noise rejection.

OBJECTIVE

Develop and demonstrate a new-class of in-flow acoustic sensors for measuring acoustic level with significantly reduced background noise based on quiet fairing/strut design and phased-microphone array signal processing methods.

APPROACH

New small microphone array sensors will be designed to be optimized for accurate level sensing in-flow rather than noise source location, reducing size and cost. New sensor fairings will be developed to minimize sensor self-noise and facilitate acoustic field mapping with multiple fixed sensors rather than traversing a single sensor. Prototypes of the new sensor will be demonstrated.

POC: Cliff Horne(ARC)



New 24-element in-flow microphone array fairing with porous Kevlar screen over microphone plate to reduce boundary layer noise. Other screen materials such as stainless steel will be evaluated. The fairing is 20.5" long x 14" wide, ABS SLS construction, and will be designed to operate at speeds up to 200 kts

SIGNIFICANCE

The development of quiet in-flow acoustic sensors will provide new flexibility, reduced cost, and improved efficiency in aeroacoustics research studies in acoustically treated or untreated closed and open test section wind tunnels. Test productivity will improve with the use of multiple fixed sensors versus a traversing set-up

Advanced Schlieren



FAP – Aeronautical Sciences Project

PROBLEM

There is a need for non-intrusive field flow measurement tools. Currently, Schlieren is used as a qualitative flow visualization tool, but has high potential to be a quantitative flow field measurement technique.

OBJECTIVE

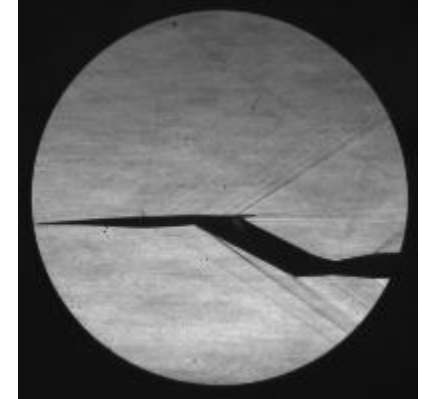
Advance Schlieren technology from a flow visualization tool to a measurement technique that can be used to make quantitative flow velocity and density measurements.

SIGNIFICANCE

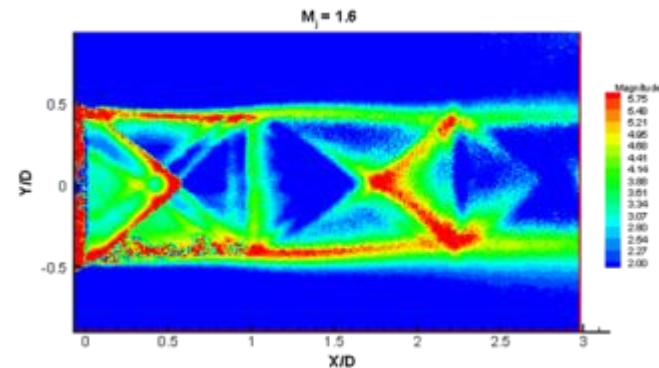
Advancements will enable the visualization of flow characteristics previously not viewable and provide the potential for quantitative velocity measurements. The development of alternate techniques like Background Oriented Schlieren provides a more robust and portable tool that can be used to provide data in non-traditional environments along with quantitative density measurements

APPROACH

- Evaluate state-of-the-art light source and knife edge (optical phase knife, etc.) improvements to traditional systems to increase sensitivity.
- Develop and demonstrate advanced Schlieren techniques (Background Oriented Schlieren & Focusing Schlieren).
- Develop a capability of acquiring quantitative flow velocity & density measurements using advanced Schlieren techniques



High speed digital images of NASA High Speed Projects / Boeing Sonic Boom Model, Fall 2012
(Right) – Acquired with “Improved” Schlieren system implemented at the 8x6



Background Oriented Schlieren technique undergoing preliminary development / demonstration on nozzle test in CW17 – Fall 2012

Advanced Internal Flow Measurements and Diagnostics



FAP – Aeronautical Sciences Project

PROBLEM

Internal flowfield measurements have been historically difficult to obtain.

OBJECTIVE

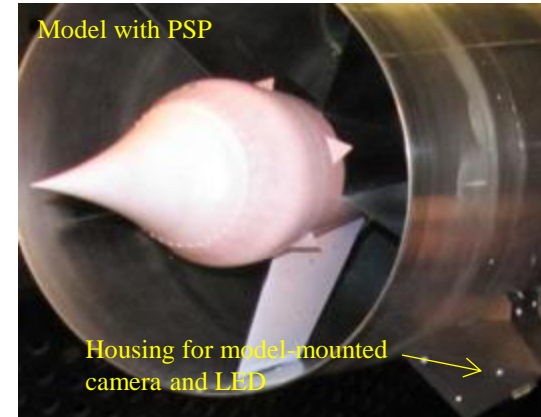
Develop the technology and technique to support optical measurements (strain, skin friction, pressure, temp) in the internal flow path of an inlet or nozzle. In the process of extending this for rotating machinery applications.

SIGNIFICANCE

Previously optical measurements could only be made in areas that were externally viewable. The ability to make global measurements in the internals of a flowpath would represent a major advancement in measurement technology and aeropropulsion system development & testing

APPROACH

- Leverage off recent efforts and developments in Surface Stress Measurement films, PSP, TSP, etc.
- The emphasis will first be on the development of a miniature camera package that can be used for acquisition
- Future research & development work are for the demonstration of this technique to make internal flowpath measurements



Large Scale Low Boom Inlet Test at the NASA GRC 8x6 Wind Tunnel (NASA-UIUC)



Optical Strain Measurement Testing –
GRC Rotordynamics Lab

Advanced Infrared Thermography



FAP – Aeronautical Sciences Project

PROBLEM

On-board IR thermography has distortion effects and lacks easily obtainable quantified information.

OBJECTIVE

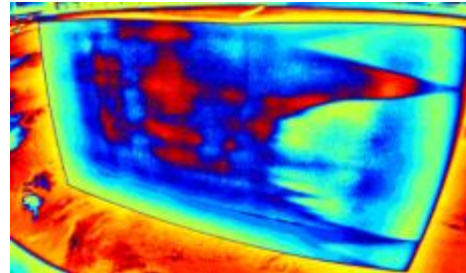
The overall objective is to be able to use infrared thermography more effectively in aerospace testing.

APPROACH

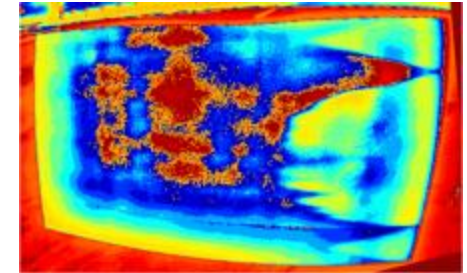
- Develop and exploit existing algorithms for geometric distortion due to camera/optics placement limitations.
- Improved methods for quantitative analysis.
- Improved and develop image processing techniques to enhance visualization of flow phenomena (shock waves, separation bubbles, etc.)
- Research multi-spectral techniques for aerodynamic measurements
- Improved sensor and hardware development

SIGNIFICANCE

Infrared thermography allows the visualization of boundary-layer transition, certain flow phenomena, and surface temperatures. IR thermography is global and non-intrusive.



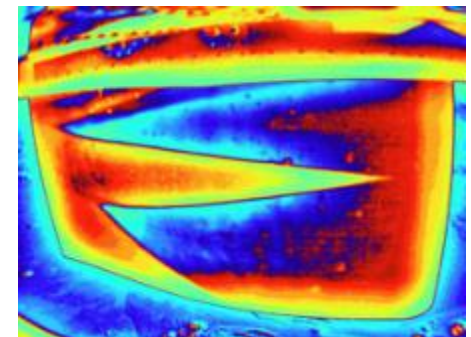
Flat plate at $M=1.6$
With geometric distortion



Flat plate at $M=1.6$
Geometric distortion partially corrected



NASA F-15B research testbed
with flat plate test article



Supersonic NLF airfoil
at transonic off-design
condition

Aeronautical Sciences NRAs



24 NRAs in excess of \$4M in support of university and industry foundational aeronautics research - highly collaborative with NASA in-house research efforts:

Revolutionary Computational Aerosciences (14)

Structures and Materials (2)

MDAO and Systems Analysis (5)

Combustion (2)

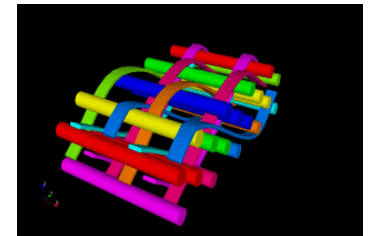
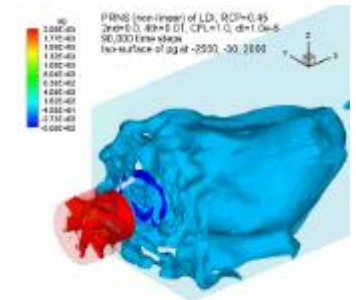
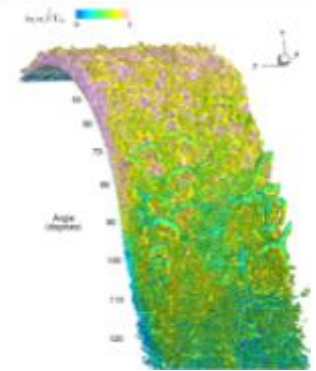
Controls (1)

<http://nspires.nasaprs.com/external/>

Aeronautical Sciences Project Summary



- Improved NASA Aeronautics program/project structure for the advancement of aeronautics research
- Exciting suite of fundamental cross-cutting research
- Aeronautical Sciences Project building toward the future, pursuing multiple collaborative and reimbursable alternatives to augment the portfolio during lean budgetary environment
- Aeronautical Sciences is the steward of NASA aero fundamental research and methods development focused on providing cross-cutting research – the lifeblood of NASA Aeronautics



Opportunities ahead with great technologies on the horizon!

http://www.aeronautics.nasa.gov/fap/aeronautical_sciences.html

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